



HPM-SVS Part-Task Simulation Documentation

Characterizing Pilot Performance During Approach and Landing With and Without Visual Aiding



Version 1

June 21, 2002

**Prepared by the Human Performance Modeling Element
of the System-Wide Accident Prevention Project
of the Aviation Safety Program**

PURPOSE

The purpose of this report is to document the specifics of the recently completed part-task simulation and to help clarify the output data for analysis and interpretation. The simulation was conducted in order to collect nominal data which would characterize pilot performance during the approach and landing phase of flight using conventional and augmented displays under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC) conditions. The test plan, rather than emphasizing statistical power, focussed on a limited number of subject pilots operating across a variety of conditions from which performance estimates could be derived.

Three types of data were collected and are described in this report: (1) time-referenced digital data concerning aircraft position and state, pilot control inputs, and eye-gaze; (2) video recordings from both an ambient room camera and eye-tracking camera with superimposed fixation cursor; and, (3) post-trial questionnaires regarding workload and situational awareness. These data are being provided to modelers for use in the development and validation of their models.

SUBJECTS

Three commercial-rated airline pilots participated in the simulation study. Two of the subject pilots currently serve as 757/767 captains while the third is a FO on 747-400. Collectively they averaged more than 11 years of commercial flying experience and more than 13,000 total flight hours (see Appendix A for summary of demographic information).

SIMULATOR

Physical Layout

A part-task simulator built by Monterey Technologies, Inc. was used for the data collection phase. The PC-based simulator approximates the instruments and controls of a Boeing-757. The aircraft simulator was linked with a visual data base modeling Santa Barbara Municipal Airport (SBA) and its surrounding terrain. The simulator consists of 4 display components as shown below in the diagram in Figure 1: The out-the-window scene (OTW), a synthetic

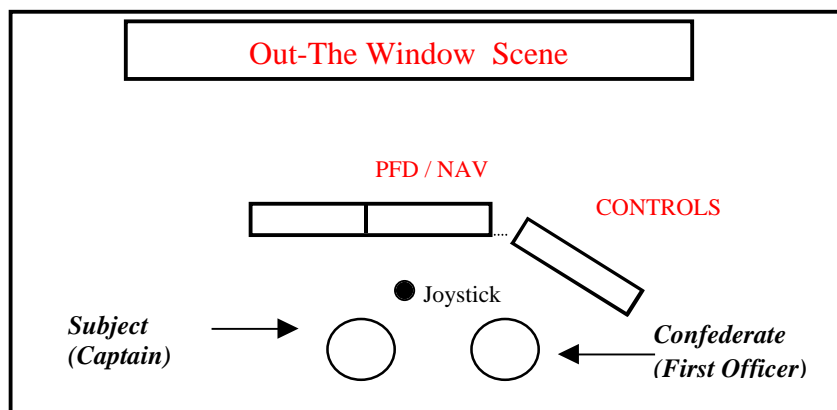


Figure 1. Diagram of physical layout of simulator components

vision system (SVS), conventional flight displays (Primary Flight Display and Navigation Display), and touchscreen software controls (MCP, Flaps, Gear, and Speed Brakes). Control inputs were made via a joystick with throttle lever, and touchscreen software buttons.

A more explicit view of the simulation is provided by two photos of the running simulation as presented in figures 2 and 3. Additionally, a set of dimensionally accurate schematic drawings is provided in Appendix B of this report so that the subtended visual angle of elements of interest to modelers can be calculated.



Figure 2. Member of the experimenter team flies a shakedown run without eye-tracking gear



Figure 3. Pilot's eye perspective of simulation displays

Simulator Displays

Out the Window (OTW) Visuals: The visual out-the-world scene (shown in Figure 4) was presented in a large front projection screen measuring 96" horizontal and 71" vertical, located 93" from pilot eye point. (see Appendix B for schematic drawings). The bottom 13" of the screen was obscured at all times by the front panel of the simulated flight deck. This left a viewable region of 96" horizontal and 58" vertical. The OTW field of view was set to a near "unity" field of view of 49.93° horizontal by 31.42° vertical.

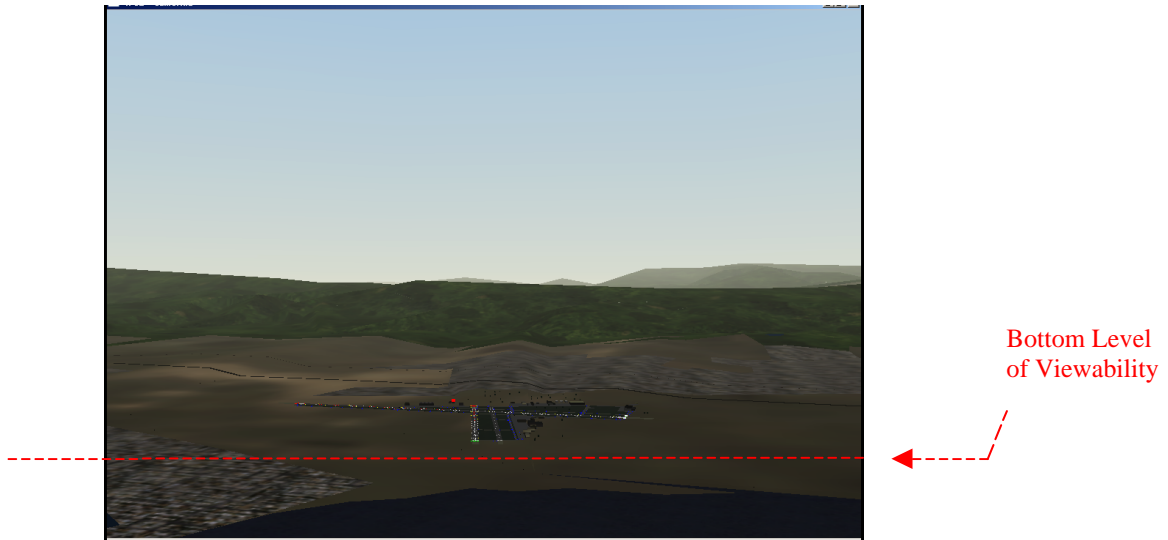


Figure 4. Out-the-Window Scene approaching Runway 33L at Santa Barbara Airport in VMC conditions -- dashed red line indicates approx. level below which screen is obscured

All simulation trials were conducted as daylight operations in either Visual Meteorological Conditions (VMC) with light haze or in Instrument Meteorological Conditions with dense fog down to 800' (or in some cases down to ground level, with 0 x 0 visibility). Presented in Figure 5 is the same Out-The-Window view as Figure 4 only in dense fog during IMC trials.



Figure 5. Out-The-Window view in dense fog during IMC trial

Synthetic Vision System (SVS): The SVS was installed as a head-down display measuring 10" horizontal by 7.5" vertical (again, see Appendix B). The display presented terrain imagery overlaid with flight-director symbology. The field of view was set at 30.7° horizontal and 23° vertical which provided a "wide-angle" perspective relative to unity. An artifact of the image generation system only noticeable at altitude and only in the SVS display (fog and haze mitigating the effect in the OTW display) was the invocation of a clipping plane which painted a continuous default ground texture at viewing distances beyond 50,000 meters (approximately 30 nm). Below in figure 6 is the SVS depiction corresponding the OTW scene in figure 4. Elements of the symbology are identified in red.

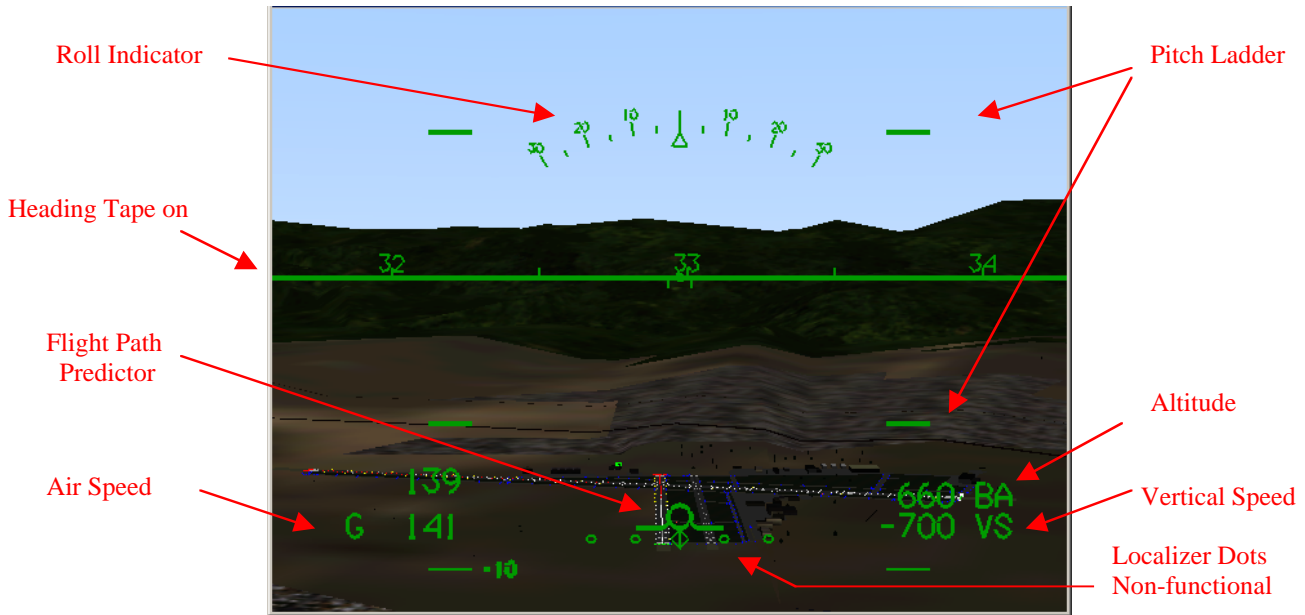


Figure 6. SVS display corresponding to the OTW scene in Figure 4 and 5 with symbology identified in red

Conventional Displays: A conventional Primary Flight Display (PFD: see figure 7) and Navigation Display (see figure 8) were presented head-down and side by side in a 5.25" by 5.25" format.

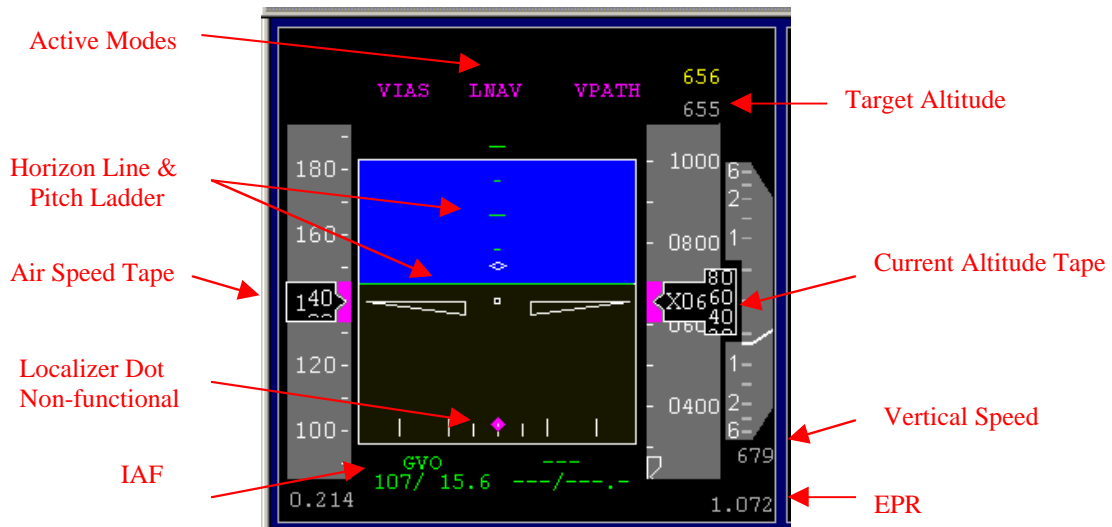


Figure 7. Primary Flight Display with symbology identified in red

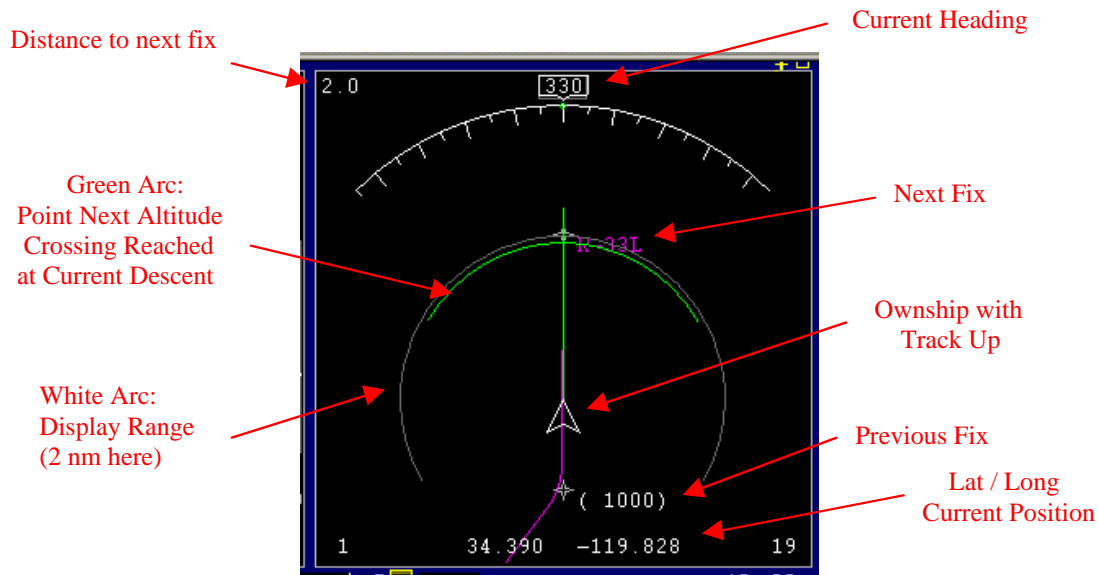


Figure 8. Nav Display with symbology identified in red

Software Controls: MCP (see Figure 9), and the gear/flap/speedbrake controls (See Figure 10) were simulated using touchscreen inputs. The confederate first officer manipulated these controls per the commands of the subject captain.

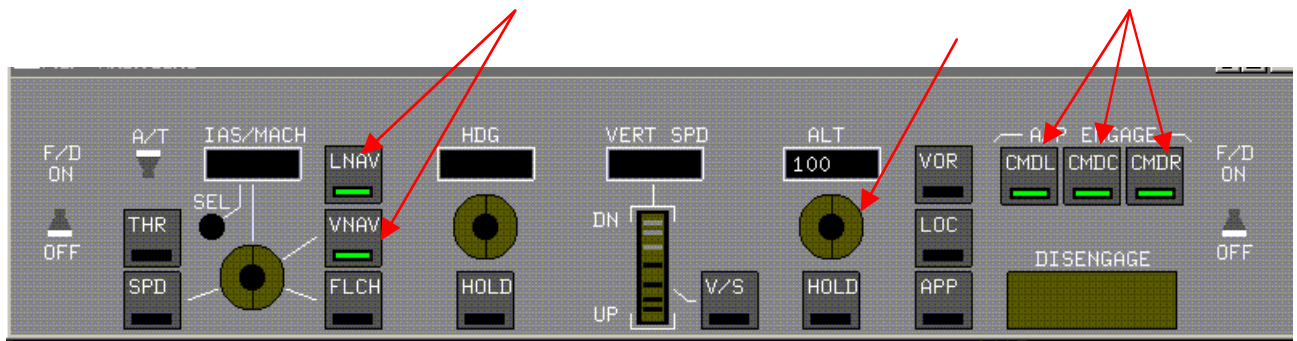


Figure 9. MCP controls presented on touchscreen display: Red arrows designate the buttons and dials needed to perform the scenarios as specified for this simulation

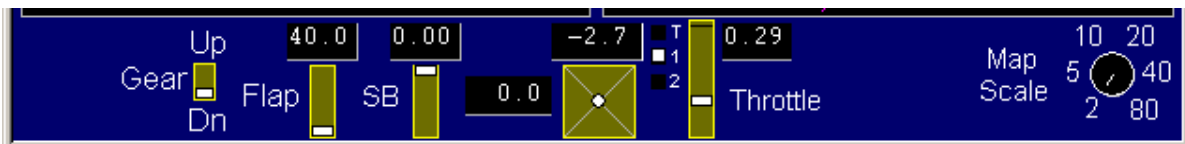


Figure 10. Gear, Flaps, and Speed Brake presented on touchscreen display

Eye Tracker:

A helmet-mounted ASL 5000 eye tracker with eye-head integration was used to collect point of gaze data from the captain. Both data stream output and a video with eye fixation overlay were recorded.

Confederate First Officer:

A confederate first officer participated in the experiment to approximate realistic crew procedures and allocation of duties. (Confederate means he was a member of the experimental team acting as a First Officer). These duties included acting on all MCP and control inputs specified by captain, making appropriate call-outs, and handling ATC communications.

Confederate ATC:

An experimenter assumed the role of ATC and provided approach and landing clearances for each trial and, on occasion, a late reassignment of runway. In no instance did ATC vector aircraft off programmed route, nor was communications to other aircraft (party line communications) simulated.

BASIC SCENARIO DESCRIPTION

Approach

The simulation focussed exclusively on daylight approach and landings to Santa Barbara Airport under calm winds. For all trials, pilots performed an RNAV (GPS) approach to Runway 33L. As this approach does not actual exist, an approach plate was constructed for the simulation based on other published RNAV (GPS) plates and shown to subjects. (see Appendix C). Pilots were required to fly this approach fully coupled to the autopilot, using LNAV and VNAV down to the 650 feet decision height (DH) at which point they took manual control. Depending on circumstance, pilots either continued the landing or declared a missed-approach and executed a go-around. It should be noted that this type of approach does not require nor make use of ground-based ILS equipment (glideslope and localizer) and represents a trend in future flight operations towards aircraft-based precision guidance.

Runway 33L was selected for use for two important reasons. First, low mountain ridges ring the backside of this runway and thus create significant terrain hazards during go-around procedures. Secondly, as there exists a closely spaced parallel runway, namely 33R, the performance of a side-step maneuver on final approach could be readily investigated. However, at 4183 feet, Runway 33L is decidedly short for commercial operations. This aspect was mitigated in the minds of subject pilots as the simulation apparatus permits descent only down to 50 feet and touchdown and roll-out of aircraft were not part of simulation runs.

Initial Conditions

All trials began at 4.1 nm inbound from the Northwest to the IAF (GAVIOTA) at 10,000 feet and 250kts with a heading of 136°. Aircraft weight was set at 200,000. The FMS was preprogrammed by the experimenter to reflect the RNAV (GPS) Runway 33L approach plate. The CDU LEGS page with its listing of fixes and associated speed and altitude restrictions (see figure 11) was shown to pilots prior to trial runs, but was not viewable during the trials.



Figure 11. LEGS page as set for the RNAV (GPS) 33L Approach

Trial Termination

Depending on scenario conditions, simulation trials led to either a landing attempt or a missed-approach. For landing trials, the trial (and data collection) was terminated when the descending aircraft reached 50 feet altitude (the minimum allowed by the simulation). For missed-approach trials, termination occurred when the ascending aircraft reached 3000 feet while executing a go-around.

Pilot Instructions

Simulation procedures were reviewed with subjects during an orientation briefing. On initiation of each trial, subjects were instructed to immediately have the FO arm the autopilots (a quirk of the simulation system required all three autopilots to be set), dial down the altitude, and engage LNAV and VNAV. Thereafter, the captain's task was to monitor and supervise the programmed FMS descent and approach, commanding such actions as flaps, speedbrakes, landing gear, and altitude settings. Utilization of MCP functions such as FLCH or VS (which might disengage LNAV or VNAV) were not permitted. At DH (650 feet) subjects took full manual control (stick and throttle) of the aircraft and either attempted the landing (i.e., descent to 50 feet) or declared a missed approach and executed a go-around.

Of particular interest was the missed approach procedure which called for a climbing 180° left turn to 5000 feet back to GOLET. This procedure was to be performed strictly as a stick and throttle effort without benefit of a "to-go" button nor MCP interventions. Additionally, subjects were advised as to how to handle certain anomalous situations: if the FO called-out traffic, subjects were to respond accordingly without the need to visually verify; if flight deck displays appeared misaligned to the O-T-W scene, subjects were to immediately discontinue the approach regardless of their ability to correct flight path.

Subjects were asked to call-out "runway in sight" (and, not to ask or rely on FO to do so), "going-around" and "misalignment" (of displays with O-T-W view) and, to freely verbalize concerns or thoughts regarding the task at hand.

Prior to the start of each trial, subjects were told only whether they would be in VMC conditions (with light haze) or IMC conditions (with ceiling down to 800 feet) and whether the SVS display would be available.

TEST PLAN

Independent Variables

Three variables of interest were investigated: Display Configuration, Visibility, and Approach Event.

Display Configuration (2)

1. Baseline Configuration

This configuration represents current-day operations and consisted of the following:

- Out-the-Window display
- Conventional Display (PFD and Nav Display)
- Software Controls (MCP, gear, flaps, speedbrakes)

2. SVS Configuration

This configuration includes all displays presented in the baseline configuration with the addition of the SVS display (Terrain with flight instrumentation overlay)

Visibility (2)

1. Visual Meteorological Conditions (VMC) -- The entire trial was conducted in day visual meteorological conditions with light haze using visual flight rules
2. Instrument Meteorological Conditions (IMC) -- The trial begins in instrument meteorological conditions following instrument flight rules. Ceiling is set at 800 feet (resulting in break-out 150 feet above DH) except for the missed-approach scenario in which dense fog continues to ground creating 0 x 0 visibility

Approach Event (4):

1. Nominal Approach

ATC issues approach clearance 3 miles from IAF (GAVIOTA) and landing clearance 2.5 miles from FAF (GOLET). No other ATC communications nor unexpected events occur and a nominal landing is performed.

2. Late Runway Reassignment

Trial begins as per nominal approach scenario. At 1000 feet on final, ATC requests that crew side-step aircraft to runway 33R due to remaining traffic on 33L. With crew acceptance, ATC then clears aircraft to land 33R with nominal landing performed. Pilots had been briefed to accept and execute this maneuver even in IMC conditions (not currently allowed) using the runway visuals provided by their SVS display. This suspension of standard operating procedures did not exempt pilots from making out-the-window visual acquisition of the newly assigned runway (after breaking through the clouds) and being stabilized before passing through DH.

3. Missed Approach

Trial begins as per nominal approach scenario. In IMC conditions, the clouds do not clear, requiring the pilot to perform a go-around. In VMC conditions, the confederate first officer announces traffic on the runway as aircraft passes 600 feet, precipitating a missed approach and go-around.

4. Terrain Mismatch

Trial begins as per nominal approach scenario. However, the instruments (PFD, NavDisplay, and SVS) are misaligned -- offset 500 feet laterally to left -- from the out-the-world view. If pilots were to follow these instruments, aircraft would touchdown 500' to the side of the runway. In essence, this is simulating an instrument failure in which the data feeding both the conventional displays and the SVS contain a 500' lateral error. The error is only noticeable to pilots upon break-out when it becomes clear that they aren't in line with the runway as expected. Pilots were expected to call-out misalignment and initiate go-around procedures.

Design

There were 10 specific combinations of variables which were investigated and designated by scenario number as shown below in Table 1. The three subject pilots were tested once across each of these 10 scenarios (save for a single lost trial). Six of the scenarios were in baseline display conditions and 4 scenarios utilized the SVS display (those all being in IMC conditions). Note that the missed approach in Scenario #3 was prompted by the FO calling out

Table 1. Test Conditions

Display Configuration		Baseline	Baseline	SVS
Visibility		VMC	IMC	IMC
Approach Event	Nominal Approach (nominal landing)	<i>Scenario #1</i>	<i>Scenario #4</i>	<i>Scenario #7</i>
	Late Reassignment (side-step & land)	<i>Scenario #2</i>		<i>Scenario #8</i>
	Missed Approach (go-around)	<i>Scenario #3</i>	<i>Scenario #5</i>	<i>Scenario #9</i>
	Terrain Mismatch (go-around)		<i>Scenario #6</i>	<i>Scenario #10</i>

traffic on the runway whereas the missed approaches in Scenarios #5 and #9 were prompted by lack of visibility at DH. Also note that Scenario #8 tested pilot's ability to perform a side-step maneuver in IMC conditions using SVS visual guidance -- a potential extension of current operational procedures.

The 10 scenarios were grouped into 3 testing blocks and presented to subjects as follows: first a 3-trial block of randomly selected baseline trials were flown, followed by a 4-trial block of SVS trials which were then proceeded by a 3-trial block of the remaining baseline trials.

DATA COLLECTION

Simulation Output

Digital output data were recorded at a *nominal* 20 Hz and included time-referenced values for aircraft position and orientation, aircraft state, and control inputs across trials. These data were merged with raw eye tracking data and converted to spreadsheet format within the files listed in Table 2.

Table 2. Listing of Data Files with Related Information

Data File Name (Subject # x Scenario #)	PcPlane Internal Clock at Start of Trial	PcPlane Internal Clock at End of Trial	Special Notes
S3Scen1.xls	1021065789.79	1021066469.41	
S3Scen2.xls	1021052513.11	1021053190.71	
S3Scen3.xls	1021070213.73	1021070947.59	
S3Scen4.xls	1021050979.42	1021051677.37	*Eye tracker data starts at 1021051066.00
S3Scen5.xls	1021053810.46	1021054535.33	
S3Scen6.xls	1021067861.36	1021068537.83	* Executed landing not Go- Around
S3Scen7.xls	1021060917.09	1021061597.11	
S3Scen8.xls	1021062005.87	1021062678.40	
S3Scen9.xls	1021059704.62	1021060443.97	
S3Scen10.xls	1021064368.55	1021065130.66	
S4Scen1.xls	1022696574.25	1022697265.69	
S4Scen2.xls	1022716487.08	1022717166.29	
S4Scen3.xls	1022704821.96	1022705571.81	
S4Scen4.xls	1022715392.20	1022716077.53	
S4Scen5.xls	1022697664.32	1022698401.01	
S4Scen6.xls	N/A	N/A	*Trial not completed
S4Scen7.xls	1022708463.73	1022709221.39	
S4Scen8.xls	1022711140.59	1022711818.51	
S4Scen9.xls	1022707150.49	1022707872.20	
S4Scen10.xls	1022712235.30	1022713009.92	
S5Scen1.xls	1022881292.24	1022881981.47	
S5Scen2.xls	1022867566.17	1022868256.00	
S5Scen3.xls	1022884021.66	1022884733.38	
S5Scen4.xls	1022866133.38	1022866827.61	
S5Scen5.xls	1022868870.43	1022869579.12	
S5Scen6.xls	1022882868.28	1022883566.86	
S5Scen7.xls	1022876204.42	1022876900.69	
S5Scen8.xls	1022878568.39	1022879254.97	
S5Scen9.xls	1022874431.63	1022875140.30	
S5Scen10.xls	1022879975.99	1022880675.54	

Collection Rate Caution

It should be noted that due to slight variations in runtime processing cycles, data was not incremented at a fixed 20 Hz rate. For this reason, caution is advised in the use of "fixed

rate" analysis programs. The computer clock time (the variable "PcPlane Internal Clock") is, however, a validly incremented timestamp and can be used accordingly.

Below in Table 3 is a listing of the variables collected along with a brief description and their column location within the data files.

Table 3. Digital Variables Collected

Column	Variable	Description
A	Phase of Flight	1 = Initialization Position to IAF (GAVIOTA) 2 = IAF (GAVIOTA) to FAF (GOLET) 3 = FAF (GOLET) to DH (650 feet) 4 = DH (650 feet) to 50 feet (Landing Trial) 4 = DH (650 feet) to 3000 feet (Go-around Trial)
B	Event	Position or Fix being crossed (per above)
C	Run State	1 = Simulation running
D	Data Collection Rate	1 = 20Hz
F	Frame Count	PcPlane frame cycles at 50msc ticks
G	PcPlane Internal Clock	Continuously running computer clock in hundredth of sec
H	X Position X-IG Internal Co-ordinates	Visual data base co-ordinate system in meters
I	Y Position X-IG Internal Co-ordinates	Visual data base co-ordinate system in meters
J	Altitude	Above mean sea level in feet
K	Pitch (Degrees)	Pitch angle in degrees, positive is up
L	Bank (Degrees)	Bank angle in degrees, positive is right wing down
M	Heading (magnetic)	
O	Ground Speed (Ft/Sec)	
P	Elapsed Range from Start (nm)	Distance <u>traveled</u> in nm from initial start point (IP)
Q	IAS (kts)	Indicated air speed
R	True Air Speed (Ft/Sec)	** same as "O"
S	Mach	Based on airspeed and altitude
T	Vertical Speed	Feet per minute
U	True Heading	
V	Weight	Gross aircraft weight
W	Flaps (degrees)	Sim settings unconventional at 4, 15, 25, & 40
X	Throttle Setting (0 - 1.0)	Throttle position whether set manually or by autopilot
Z	Speed Brake Setting (0 - 1.0)	Proportion of extension
AA	Landing Gear	0 = stowed, 1 = fully deployed
AB	Latitude	Current position in decimal latitude
AC	Longitude	Current position in decimal longitude
AD	Joystick X (-1 thru +1)	Positive values indicate stick pulled aft
AE	Joystick Y (-1 thru +1)	Positive values indicate stick deflection to the right
AF	gamma_d	Legacy parameter of unknown type
AH	gamma_hold	Legacy parameter of unknown type
AJ	bank (radians)	Bank angle in radians, positive values are right wing down
AK	Heading Hold (degrees)	Computed target heading
AM	MCP Speed Window	Displayed value on MCP
AN	MCP Hdg Window	Displayed value on MCP
AP	MCP VS Speed Window	Displayed value on MCP
AQ	MCP Altitude Window	Displayed value on MCP
AR	Speed Mode Engaged (Light)	TBD
AS	Heading Mode Engaged (Light)	TBD

AT	VS Mode Engaged (Light)	TBD
AU	Altitude Hold Engaged (Light)	TBD
AV	MCP SEL Knob	SEL Knob set
AW	MCP Spd Knob	SPD Knob set
AX	MCP Hdg Knob	Hdg Knob set
AY	MCP Speed	Speed mode: 0 = off, 1 = Engaged
BA	MCP Alt Knob	Alt Knob set
BB	MCP Speed Dial	Speed Dial setting
BC	MCP Hdg Dial	Heading Dial setting
BD	MCP VS Dial	VS Dial setting
BE	MCP Alt Dial	Altitude Dial setting
BF	MCP CMDL	Left Autopilot mode: 0 = off, 1 = Engaged
BH	MCP LNAV	LNAV mode: 0 = off, 1 = Engaged
BI	MCP VNAV	VNAV mode: 0 = off, 1 = Engaged
BJ	MCP FLCH	FLCH mode: 0 = off, 1 = Engaged
BK	MCP Hdg Hold	Heading Hold mode: 0 = off, 1 = Engaged
BL	MCP V Speed	Vertical Speed mode: 0 = off, 1 = Engaged
BM	MCP Alt Hold	Altitude Hold mode: 0 = off, 1 = Engaged
BO	MCP CMDC	Center Autopilot mode: 0 = off, 1 = Engaged
BP	MCP CMDR	Right Autopilot mode: 0 = off, 1 = Engaged
BQ	Eye Track Status	128 = Active
BR	Pupil Most	Intermediate parameter -- ignore
BS	Pupil Least	Intermediate parameter -- ignore
BT	Scene Plane	Sceneplane 0 = Undefined or invalid data Sceneplane 1 = Out-the-Window (OTW) View Sceneplane 2 = SVS Display Sceneplane 3 = Primary Flight Display Sceneplane 4 = Nav Display Sceneplane 5 = Mode Control Panel Sceneplane 6 = Controls (Flaps, gears, speedbrakes, map scale) Sceneplane 7 = Overlapping Area
BU	POG Y Most	Intermediate parameter -- ignore
BV	POG Y Least	Intermediate parameter -- ignore
BW	POG Z Most	Intermediate parameter -- ignore
BX	POG Z Least	Intermediate parameter -- ignore
BZ	HPM Latitude Offset	SVS & NAV Display misalignment in feet (always 0)
CA	HPM Longitude Offset	SVS & NAV Display misalignment in feet (0 or -500)
CB	Pupil Size	0 = closed, if so invalidates other eye tracker variables
CC	POG Y	Horizontal offset in inches from sceneplane origin
CD	POG Z	Vertical offset in inches from sceneplane origin

EYE TRACKER DATA

General Notes:

The raw eye tracker data is provided in the simulation output file at 20 hz without any filtering or smoothing of the data. This raw data is provided so that you may perform your own processing of the data if you choose to do so. Some filtering and smoothing of the data will likely be required to make meaningful interpretations of the data. Noise in the data may be due to several sources such as blinking or a temporary loss of eye tracker calibration.

Variables:

- Sceneplane
- Pupil Size
- Point of Gaze (POG) Y
- Point of Gaze (POG) Z

Other variables in the data set including POG Y most, POG Y least, POG Z most, POG Z least, pupil most, and pupil least were used to generate the final data variables listed above, but are no longer needed for analyses (you can ignore these).

Sceneplane (SP)

There are eight sceneplanes, each described below (also see schematic below)

Sceneplane 0 = Undefined or invalid data. Occurs when the eye cursor is centered on an area that is not defined as sceneplane 1 to 7 – i.e. the first officer, joy stick etc - or if the data is invalid (i.e. subject blinks).

Sceneplane 1 = Out-the-Window (OTW) View

Sceneplane 2 = SVS Display

Sceneplane 3 = Primary Flight Display

Sceneplane 4 = Nav Display

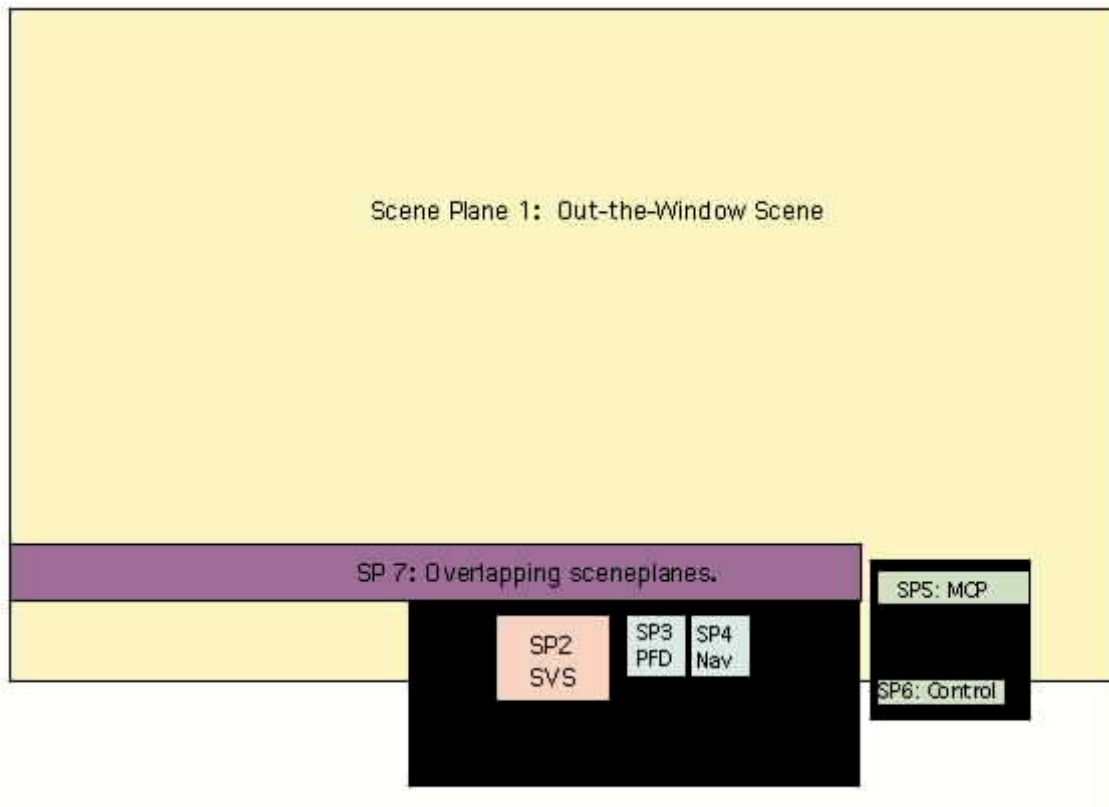
Sceneplane 5 = Mode Control Panel

Sceneplane 6 = Controls (Flaps, gears, speedbrakes, map scale)

Sceneplane 7 = Overlapping Area. The cockpit displays sit directly in front of the lower portion of the OTW view. Depending on the viewing angle of the subject (which varied slightly by subject, and over the day of trials), the eye tracker could not always determine whether the subject was looking at the black masking area around the displays, or the OTW view behind the masking. In these cases, the sceneplane is recorded as “7”.

Given that the bottom of this sceneplane is 2 inches above the top of the SVS, PFD, and Nav display, it is doubtful that the subject was gathering data from the displays when the eye point of gaze was in this region. Further, a sub-sampling of the video tapes revealed that glances in this region are best attributed as glances to the out-the-window scene. If you intend to use these data points to determine ‘first glances’ to the OTW scene, or other similar purposes, you may find the context of the scenario, provided in the eye tracker video tape, useful to verify that glances in this region are indeed to the OTW view.

Overview of ScenePlane Layout



Pupil Size:

If pupil diameter = 0, the eye is closed. The data is not valid for any of the eyetracker variables (scene plane, POG Y, POG Z).

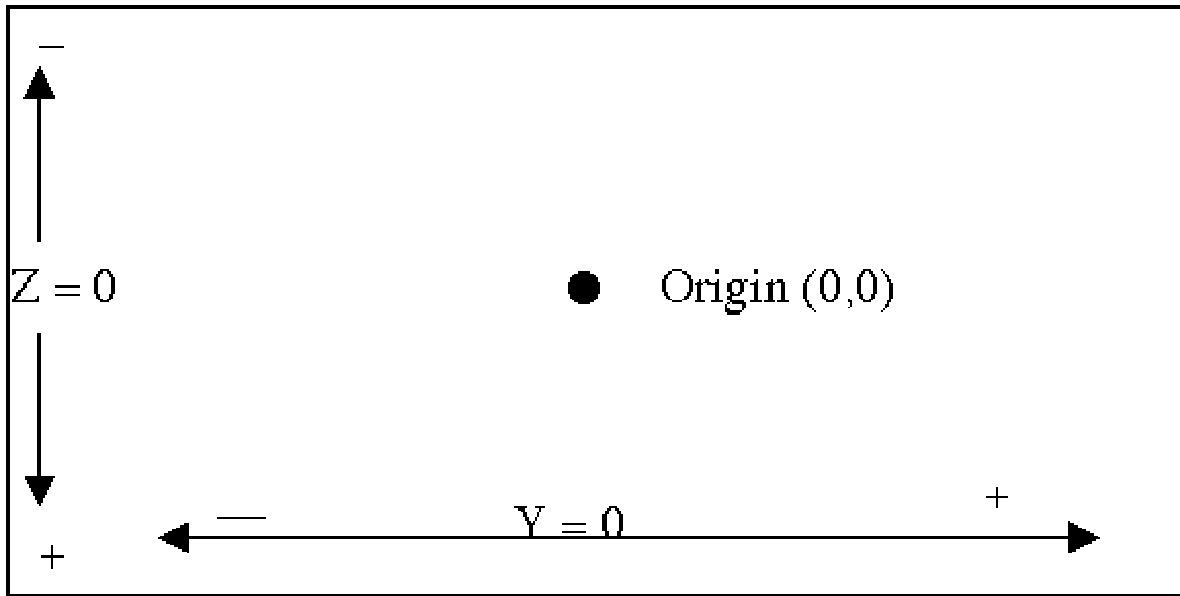
Point of Gaze (POGY and POG Z):

POG represents the Y (horizontal) and Z (vertical) coordinates in inches, relative to the origin of the sceneplane.

For each visual display (sceneplane 1,2,3,4,5,6) the origin is the exact center point of the display. Any point on the display can be characterized by their (Y,Z) coordinates. At the origin, Y = 0, and Z = 0. To the right of origin, Y values are positive and increase. To the left of origin, Y values are negative and decrease. Below the origin, Z values are positive and increase. Above the origin, Z values are negative and decrease.

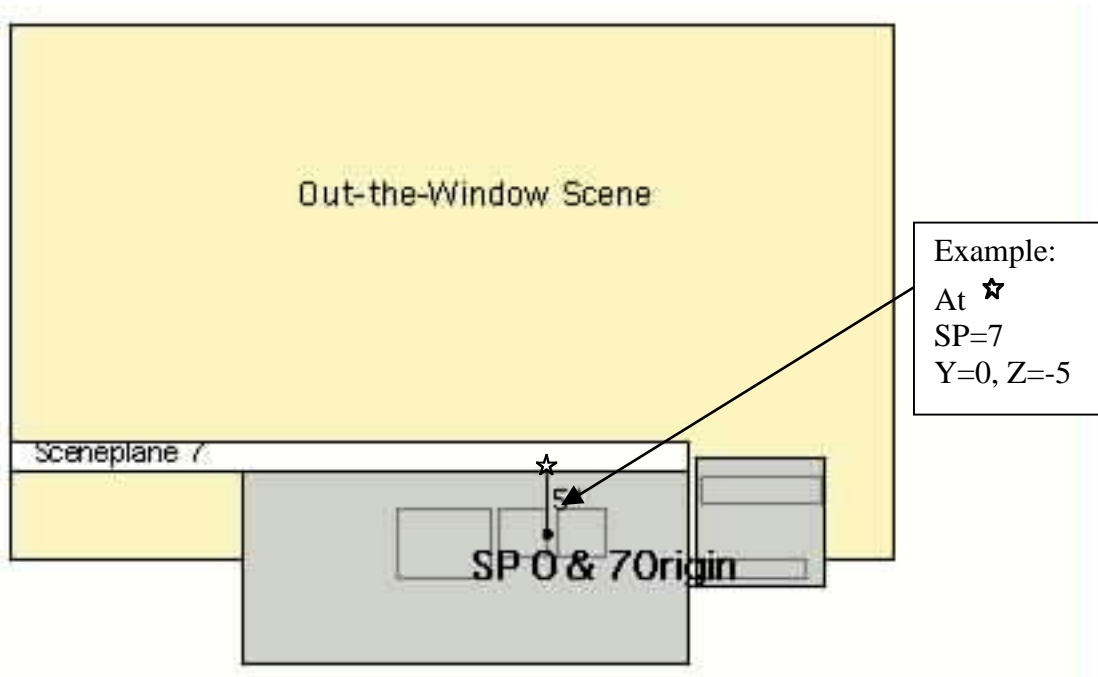
Example. A point 1" to the right of origin, and 3" above origin would have coordinates: Y=1, Z=-3.

POG Coordinates, relative to the origin of a sceneplane (visual displays)



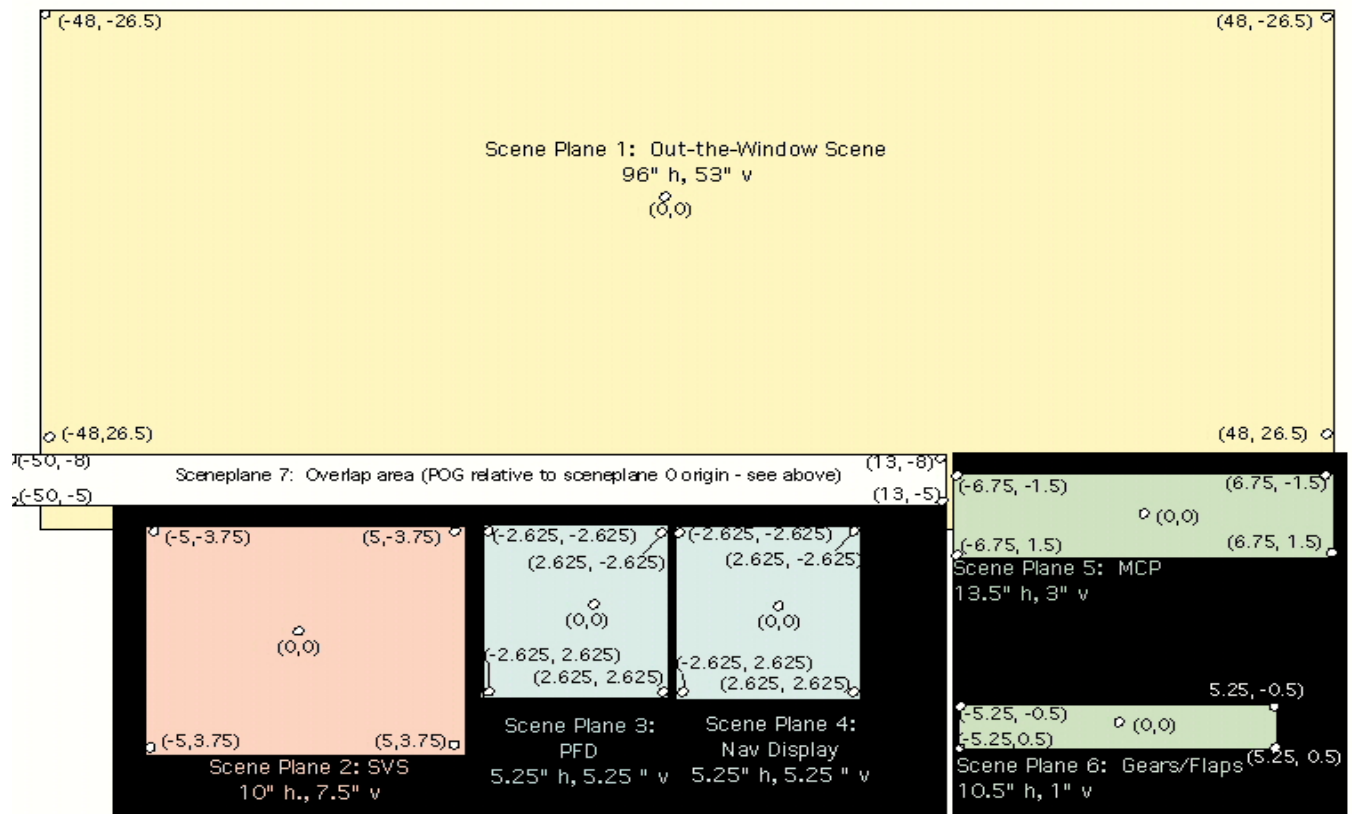
Sceneplane 0 and 7 share the same origin as shown by the black circle in the schematic below. POG Y and Z for both sceneplanes are represented in inches from this origin. For example the Y,Z coordinates for the point identified by the star in sceneplane 7 below would be sceneplane 7, (Y=0, Z=-5).

POG Coordinates. Origin Location for ScenePlane 0 and 7



The figure below illustrates the seven sceneplanes, and the POG Y and POG Z values that identify each corner of the plane.

POINT OF GAZE COORDINATES (inches) (Y,Z)



Note: Where possible, buffers were added around edges of the displays to allow a slight margin of error (except where sceneplanes would overlap). Therefore it is possible to have POG coordinates slightly larger than those shown above.

Audio and Video Recordings

Eye Tracker Camera

For each trial a videotape of the pilot's forward view was recorded from the head-mounted eye tracker. The pilot's point of gaze is shown by crosshairs superimposed over the visual scene. These tapes provide a fair representation of what the pilot was actually seeing at any given point in the simulation.

Room View Camera

Additionally, for each trial an ambient audio and video recording was produced that depicts displays and control inputs and verbal communications. Three audio channels were recorded as follows: left channel was the Captain (subject), right channel was the FO (experimenter), and center channel was ATC (experimenter). It should be noted that the camera was mounted high and behind the pilot and that the visual perspective in the tapes is not that of the pilot.

Annotated versions of these video recordings have been prepared for distribution to modelers and are listed below in Table 5.

Table 5. Listing of Annotated Video Tapes

Subject #3, Tape #1

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
4			
start	1:48:56	0:01:15 VIDEO LOST	0:01:00
Stop	1:59:15	0:01:15 VIDEO LOST	0:11:30
2			
start	2:13:00	0:01:22 VIDEO LOST	0:11:52
Stop	2:25:33	0:01:22 VIDEO LOST	0:23:45
5			
start	2:34:37	0:01:35	0:24:12
Stop	2:47:00	0:14:00	0:36:50
9			
start	4:12:48	0:14:22	0:37:00
Stop	4:25:10	0:27:02	0:49:50
7			
start	4:33:00	0:27:25 VIDEO LOST	0:50:00
Stop	4:44:20	0:27:25 VIDEO LOST	1:01:50
8			
start	4:51:06	0:27:58	1:02:20
Stop	5:02:35	0:39:47	1:14:05

Subject #3, Tape #2

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
10			
start	5:30:05	0:01:07 VIDEO LOST	0:01:18
Stop	5:43:12	0:01:07 VIDEO LOST	0:14:00
1			
start	5:54:06	0:01:36 PARTIAL VIDEO LOSS	0:14:36
Stop	6:05:37	0:10:58 PARTIAL VIDEO LOSS	0:26:26
6			
start	6:28:35	0:11:20 VIDEO LOST	0:26:32
Stop	6:40:04	0:11:20 VIDEO LOST	0:38:21
3			
start	7:07:47	0:11:38 VIDEO LOST	0:38:31
Stop	7:20:05	0:11:38 VIDEO LOST	0:51:10

Subject #4, Tape #1

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
1			
start	1:55:35	0:01:04	0:01:07
Stop	2:07:04	0:12:56	0:13:00
5			
start	2:13:44	0:13:08	0:13:15
Stop	2:26:05	0:25:49	0:26:09
3			
start	4:12:56	0:26:04	0:26:27
Stop	2:47:00	0:38:56	0:39:00
9			
start	4:51:42	0:39:08	0:39:37
Stop	5:03:49	0:51:38	0:52:09
7			
start	5:13:33	0:51:44	0:52:26
Stop	5:25:00	1:03:30	1:04:16

Subject #4, Tape #2

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
8			
start	5:58:00	0:01:15	0:01:02
Stop	6:09:28	0:12:59	0:12:49
10			
start	6:16:20	0:13:12	0:13:05
Stop	6:29:24	0:26:38	0:26:28
4			
start	7:08:56	0:26:46	0:26:48
Stop	7:20:10	0:38:32	0:38:20
2			
start	7:27:09	0:38:47	0:38:36
Stop	7:38:32	0:50:37	0:50:25

Subject #5, Tape #1

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
4			
start	0:39:14	0:01:15	0:01:03
Stop	0:51:00	0:13:15	0:13:04
2			
start	1:03:16	0:13:30	0:13:17
Stop	1:14:51	0:25:30	0:25:32
5			
start	1:24:59	0:25:43	0:25:45
Stop	1:36:51	0:37:55	0:37:59
9			
start	4:51:42	0:38:09	0:38:10
Stop	5:03:49	0:50:20	0:50:27
7			
start	3:27:06	0:50:37	0:50:39
Stop	3:38:40	1:02:30	1:02:42

Subject #5, Tape #2

<u>Scenario</u>	<u>Time-Code</u>	<u>Room-Camera VCR Time</u>	<u>Eye-Camera VCR Time</u>
8			
start	4:06:28	0:01:15	0:00:58
Stop	4:17:57	0:13:10	0:12:53
10			
start	0:08:48	0:13:25	0:13:07
Stop	0:20:31	0:25:29	0:25:10
1			
start	0:30:42	0:25:40	0:25:19
Stop	0:42:13	0:37:29	0:37:12
6			
start	0:56:59	0:37:37	0:37:25
Stop	1:08:42	0:49:48	0:49:38
3			
start	1:16:10	0:50:04	0:49:48
Stop	1:28:05	1:02:30	1:02:08

Post-Trial Workload and SA Questionnaires

After each trial a questionnaire was given in which subjects rated on a 1 - 7 scale various aspects of their perceived workload and situational awareness across different phases of the just completed flight (see Table 5). A summary of subject responses is provided in spreadsheet format under the file name *QuesData.xls*.

Table 5. Questions and Rating Scale Used in Post-Trial Questionnaire

1. Please rate your situation awareness and workload for the entire trial that you just completed.
2. Please rate your situation awareness and workload for the period of time from the Initial Approach Fix to the Final Approach Fix.
3. Please rate your situation awareness and workload for the period of time from the Final Approach Fix to the point where you took over manual control of the aircraft.
4. Please rate your situation awareness and workload for the period of time from when you took over manual control to the end of the trial
5. Please rate your situation awareness and workload associated with the task of making a visual fix on the runway.
6. Please rate your situation awareness and workload associated with the task of making the decision to accept the side-step maneuver
7. Please rate your situation awareness and workload during the side step maneuver.

-- OR --

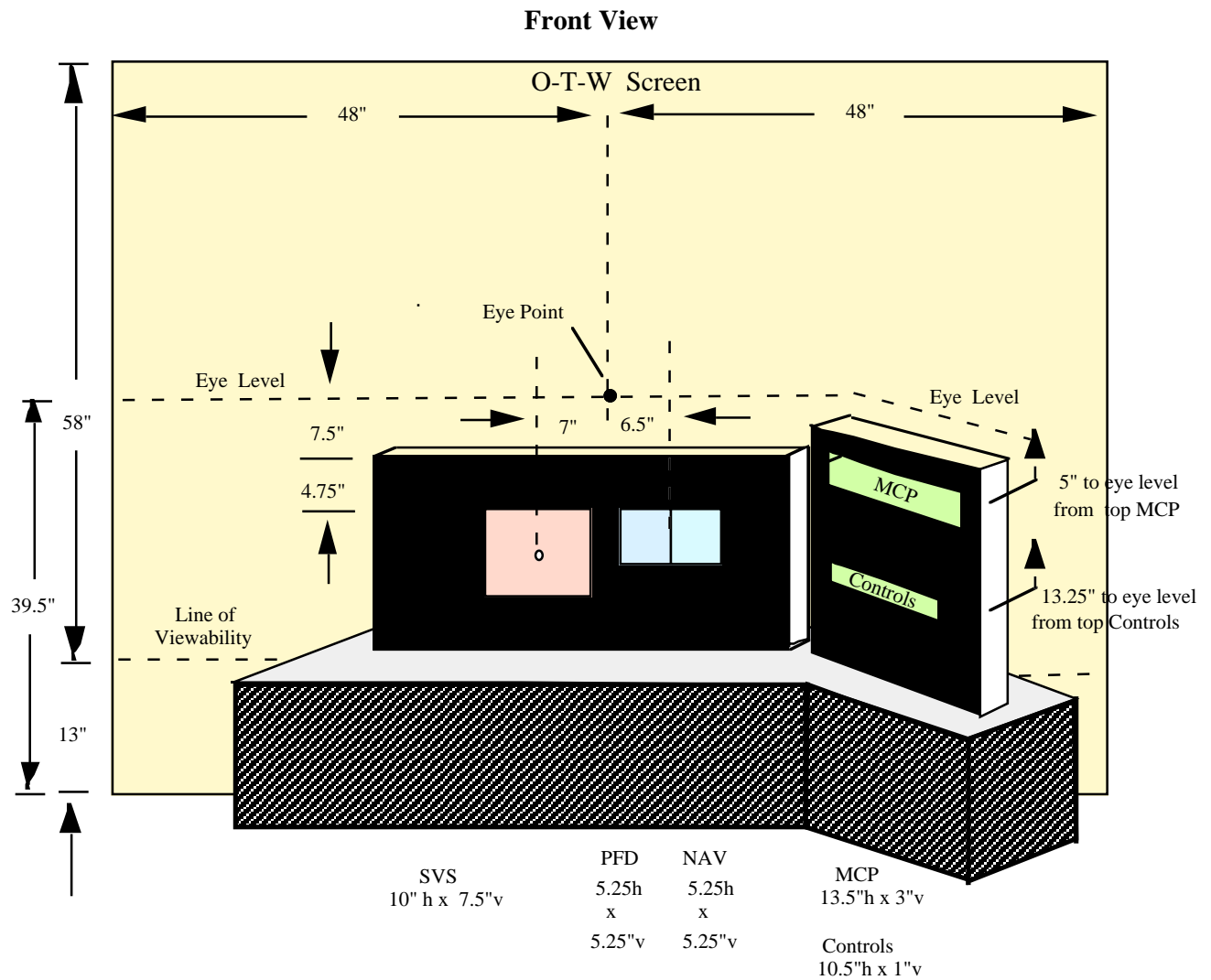
6. If you executed a missed approach or go around during this trial, please rate your situation awareness and workload associated with the task of making the decision to initiate the missed approach.
7. If you executed a missed approach or go around during this trial, please rate your situation awareness and workload during the maneuver -- i.e. from the time you initiated the maneuver to the end of the trial.

	Low		Neutral			High	
Overall situation awareness	1	2	3	4	5	6	7
Awareness of terrain	1	2	3	4	5	6	7
Awareness of position relative to runway	1	2	3	4	5	6	7
Awareness of cockpit display information	1	2	3	4	5	6	7
Overall workload	1	2	3	4	5	6	7
Visual workload	1	2	3	4	5	6	7
Auditory workload	1	2	3	4	5	6	7
Cognitive workload	1	2	3	4	5	6	7
Psychomotor (physical) workload	1	2	3	4	5	6	7

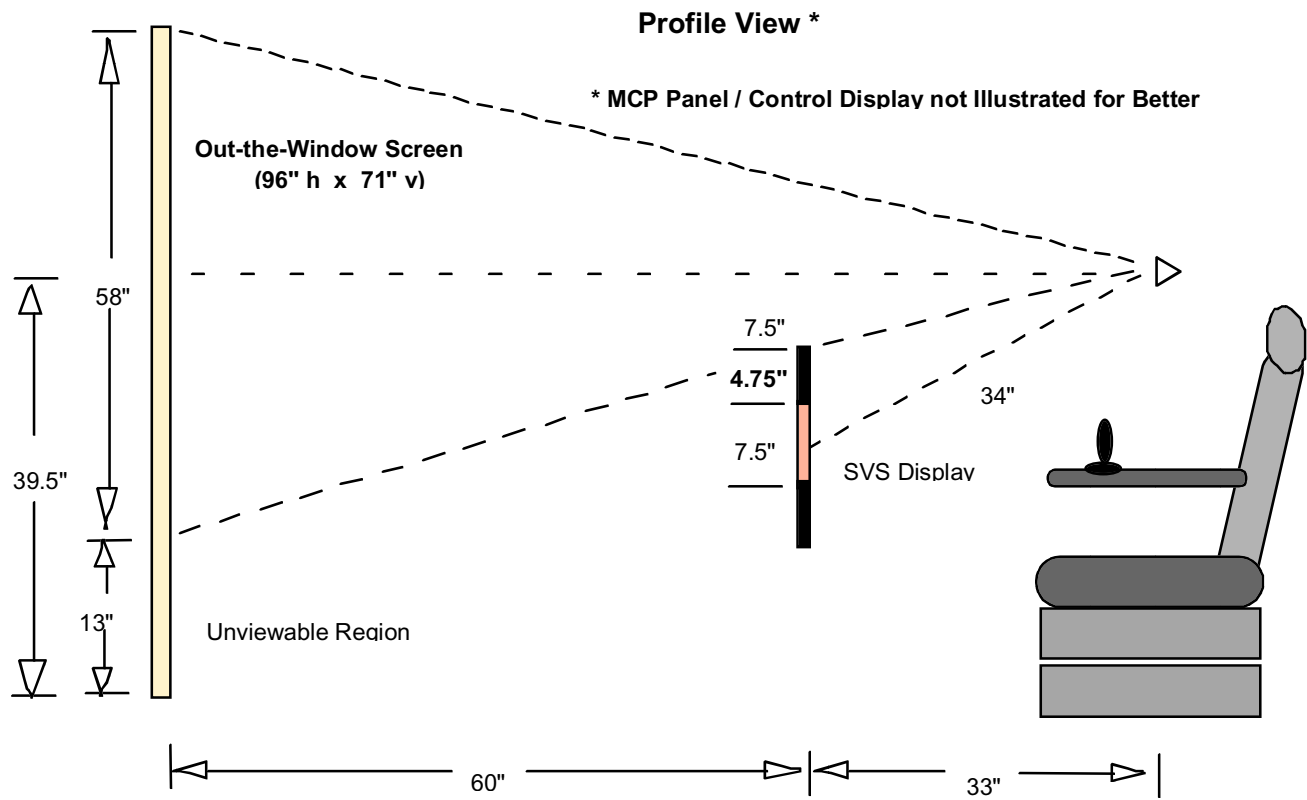
Appendix A: Summary of Demographic Information

	Sub 3	Sub 4	Sub 5
1. Current position:	Captain	First Officer	Captain
2. Current aircraft operated:	B767/B757	B747-400	B757/767
3. Hours logged on current aircraft:	5000+	1100	800
4. Years flying commercially- Total:	17	10	7
As Captain:	10		4
As FO:	7	10	3
5. Hours logged- Total:	16000	12000	11000
Glass equipped aircraft:	9000	5000	2000
6. Have you ever used a head-up display(HUD):	No	No	Yes
How many hours logged with HUD:			100
7. Have you ever used a terrain awareness display(TAD):	Yes	No	Yes
How many hours logged with TAD:	2000		1500
8. Have you ever flown into Santa Barbara Municipal Airport:	Yes	No	Yes
How many times:	50		4

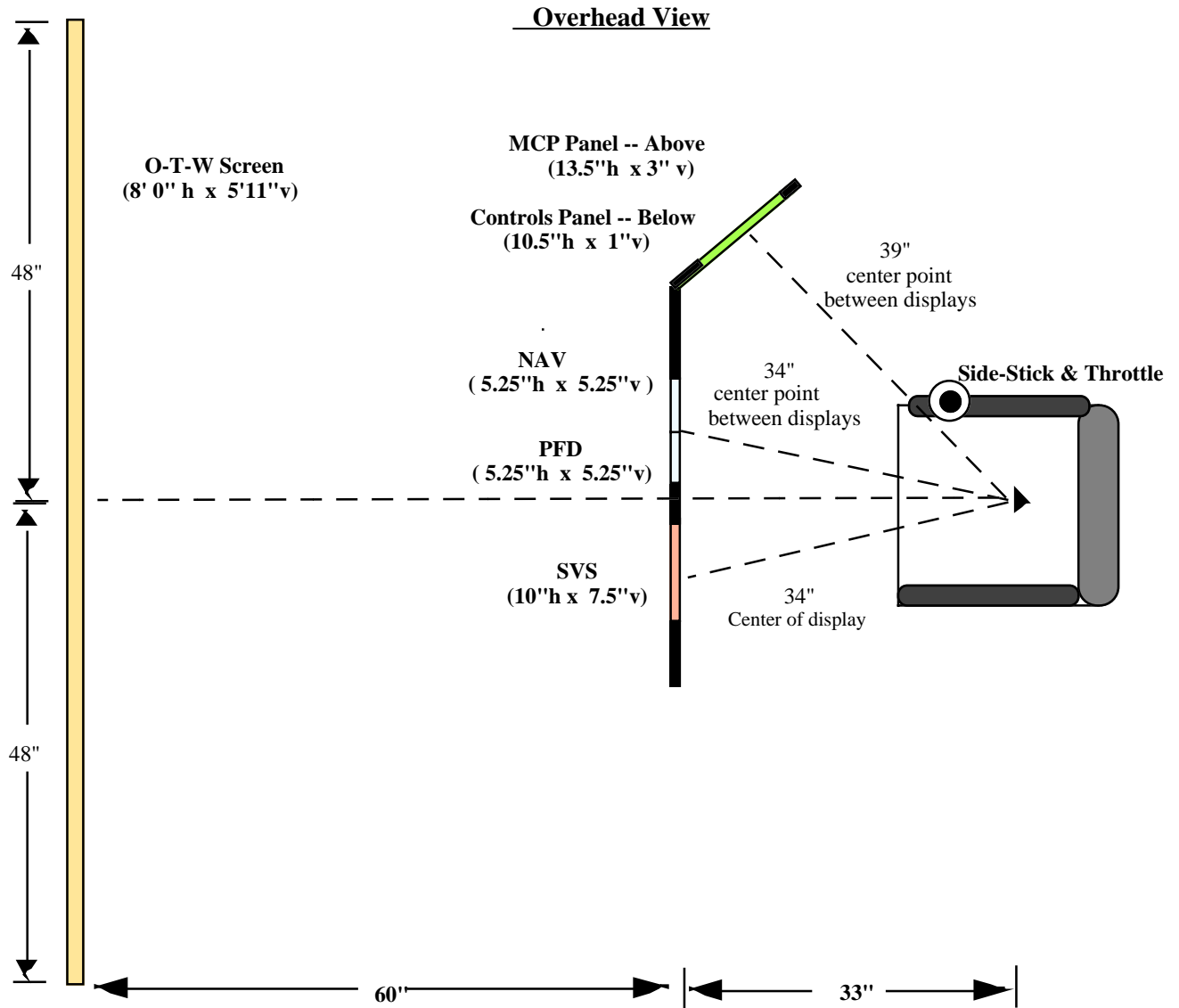
Appendix B: Schematic of Simulation Set-up



Appendix B: Schematic of Simulation Set-up



Appendix B: Schematic of Simulation Set-up



Appendix C: Approach Plate

